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MEASUREMENTS OF SOLIDS CONCENTRATION IN COAL SLURRIES USING MICROWAVES

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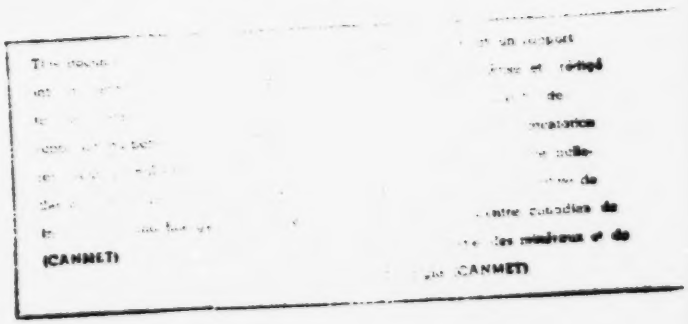

MICROMEDIA

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MEASUREMENT OF SOLID CONCENTRATION IN COAL SLURRIES USING MICROWAVES

by

Nagi A. Mansour*

ABSTRACT

This paper presents a new potential application of microwaves in the coal industry, that is, measuring solids content of a coal-water slurry. Recent dielectric data on coal and water are given and discussed. Results indicate that the microwave absorption technique gives better sensitivity when compared to dielectric measurements.

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UTILISATION DES MICRO-ONDES POUR MESURER LA CONCENTRATION DES SOLIDES DANS LES BOUILLIES DE CHARBON

par

Nagi A. Mansour*

RÉSUMÉ

Le présent rapport porte sur une nouvelle application possible des micro-ondes dans l'industrie du charbon, à savoir la mesure de la teneur en solides des bouillies charbon-eau. De récentes données diélectriques sur le charbon et l'eau sont présentées et expliquées. Les résultats indiquent que la spectroscopie à micro-ondes donne des résultats plus précis que les mesures de la constante diélectrique.

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INTRODUCTION

Reliable, versatile and economic measurement techniques and instrumentation are vital for monitoring the composition, particle size distribution, and solids concentration of coal slurries. This is important in the transportation and storage of coal slurries and for automation and process control in coal washing plants. The commonly used gamma ray techniques meet some of these requirements, but alternative techniques are needed to provide the faster response times required in real-time controlling, and to minimize the detrimental effects of entrapped air on measurement accuracy. Furthermore, the technique should be compatible with microprocessor controlled systems and be operable in a field environment. This implies that the output signals should be electrical in nature, without any intervening electromechanical parts, and that the instrumentation should be remotely controlled by a computer.

Non-contact microwave electromagnetic measurement (EM) techniques promise to compliment and even to supercede most of the currently used gamma ray methods. These techniques are being introduced in the sensing stages of automatic process controllers in the food, wood, and grain handling industries and are also becoming popular in various material treatment plants. The techniques are essentially used for measurement of the moisture content of the processed material. They rely on the fact that the dielectric constant of water, highly polar liquid, is distinctively higher than that of many industrial materials. In the microwave frequency range, the polarization of water molecules becomes ineffective, which results in an increase in the polarization absorption of EM energy. The differences in absorption of microwave energy by various constituents of the industrial media can then be used for the identification of its composition.

To date, the absorption based microwave techniques have only been applied to media with low moisture content. This paper will present a new potential application of microwaves in the coal industry, that is, measuring solids concentration in the coal-water slurry.

DIELECTRIC CHARACTERISTICS OF WATER AND COAL

Coal Slurries also contain entrapped air and various inorganic substances which can be ignored to simplify our discussion. The dielectric characteristics of water have been extensively investigated, starting with the often quoted fundamental investigations of Von Hippel [1]. The results of recent and also more accurate measurements by Burdette et al and others [2] are shown in Figure 1.

The dielectric characteristics of coal have received much less attention and are not uniquely defined. This is because the characteristics change, depending on the type, physical shape, processing method, and moisture content of the coal. Moreover, they also depend on measurement frequency. For further discussion, we have selected the characteristics of pulverized Pittsburgh coal reported by Nelson et al [3] and summaried in Figures 2 and 3. The most important curves are those denoted run-of-mine (ROM). The light and dense fractions denoted by 1.3 float and 2.0 sink were separated from ROM coal by heavy media gravitational techniques to obtain materials with low and high pyrite content. The dielectric characteristics of coal are essentially frequency independent from 1 MHz to a few MHz. Many coal types enter the transition region at about 10 MHz. However, the dielectric loss factor of all coals levels off around 1 GHz and remains constant even above 10 GHz. Furthermore, the absolute value for most ROM coals is about 0.05 with few materials approaching the 0.1 value reported for Pittsburg coal (Figure 3).

In comparing the frequency dependence of water and coal to absorb in the microwave range, we can conclude that they are distinctly different. The relative dielectric constants seem to have essentially similar frequency dependence, although their absolute values differ significantly. On the other hand, the relative loss factors start at low values in the 100 MHz range, and in the microwave frequency range, they show a completely opposite frequency dependence. Around 10 GHz, their values differ by a factor of many hundreds. Thus, the absorption of microwave energy offers an excellent

opportunity to investigate the proportion of the two major components, i.e. water and coal, of coal slurries. Furthermore, the strong frequency dependence of the dielectric loss factor of water offers the opportunity to obtain independent measurements provided they are taken at frequencies which are about 0.5-1.0 GHz apart.

MEASUREMENT SET-UP

It was originally assumed that dielectric constant related characteristics of coal slurries would lead to the best measurement sensitivity. On the other hand, it was only possible to perform the absorption measurements due the limited availability of microwave hardware. Two horns and a sample holder housed in an aluminum box were used to perform measurements in the frequency range between 6 and 12.5 GHz.

Experiments were made with various shapes of material holders and different measurement procedures. The interaction region was eventually simplified using a rectangular container made of plexiglass. The cross-section of the container was many times larger than the horn opening. During the measurements, the microwave energy passed through a slab of the investigated media, which can be assumed to extend many wavelengths beyond the radiating area of the horns. Figure 4 shows the ratio between the available transmitted power for coal and water. The data shows that sensitivity can be improved by using a microwave absorption technique in the GHz range.

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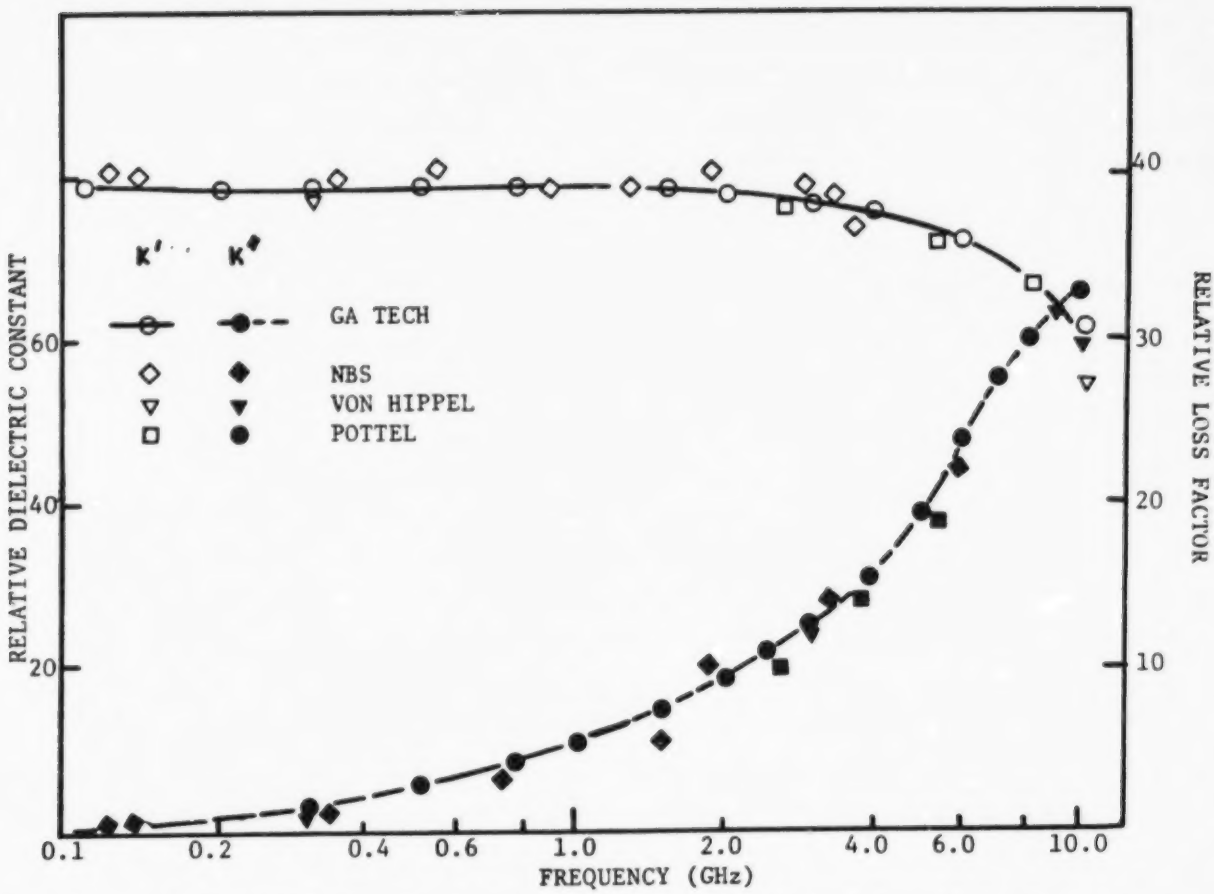

Figure 1. Experimentally determined relative dielectric constant and relative loss factor of deionized water at 23°C [2,4-6].

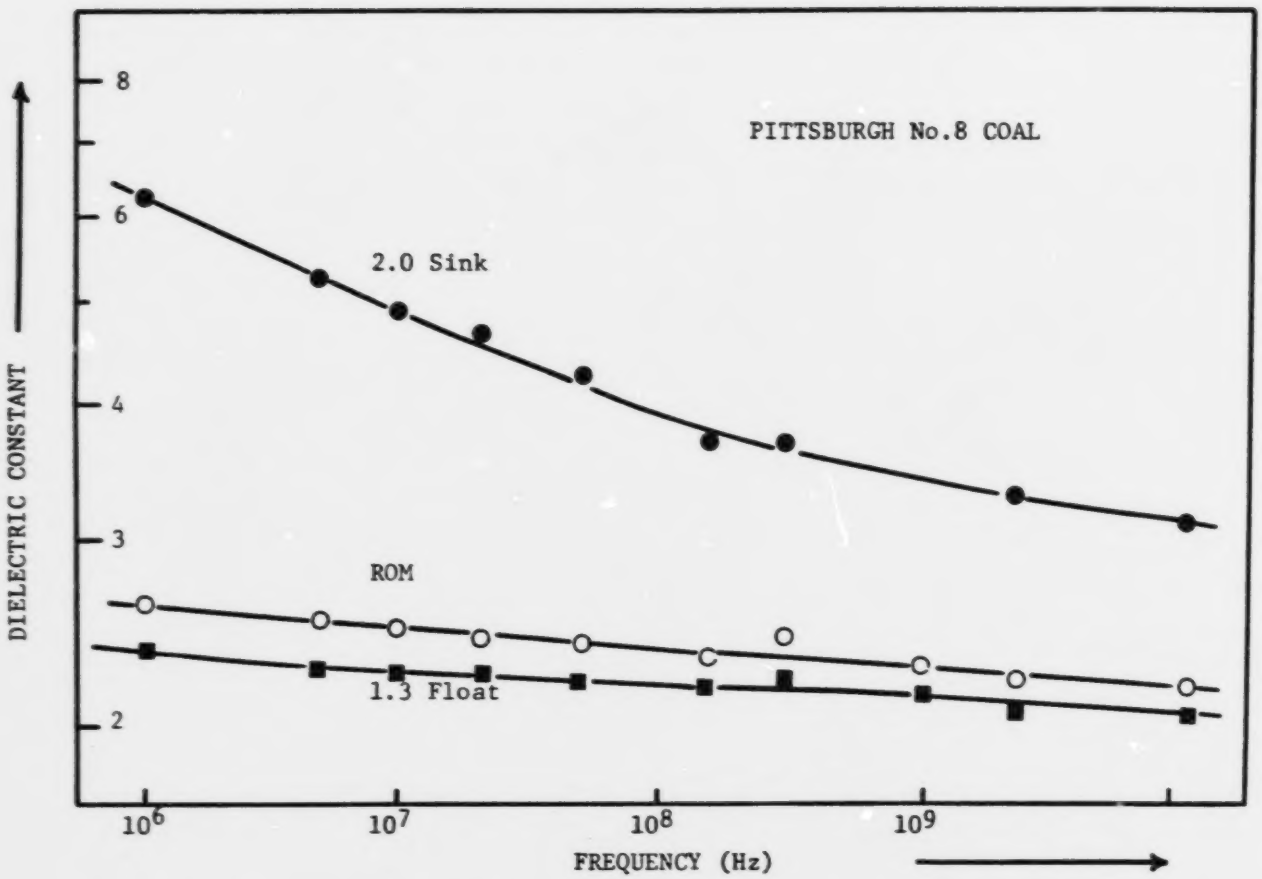

Figure 2. Frequency dependence of the dielectric properties of Pittsburgh No.8 pulverized coal at 22°C; run-of-mine (ROM), light (1.3 Float) and dense (2.0 Sink) fractions.

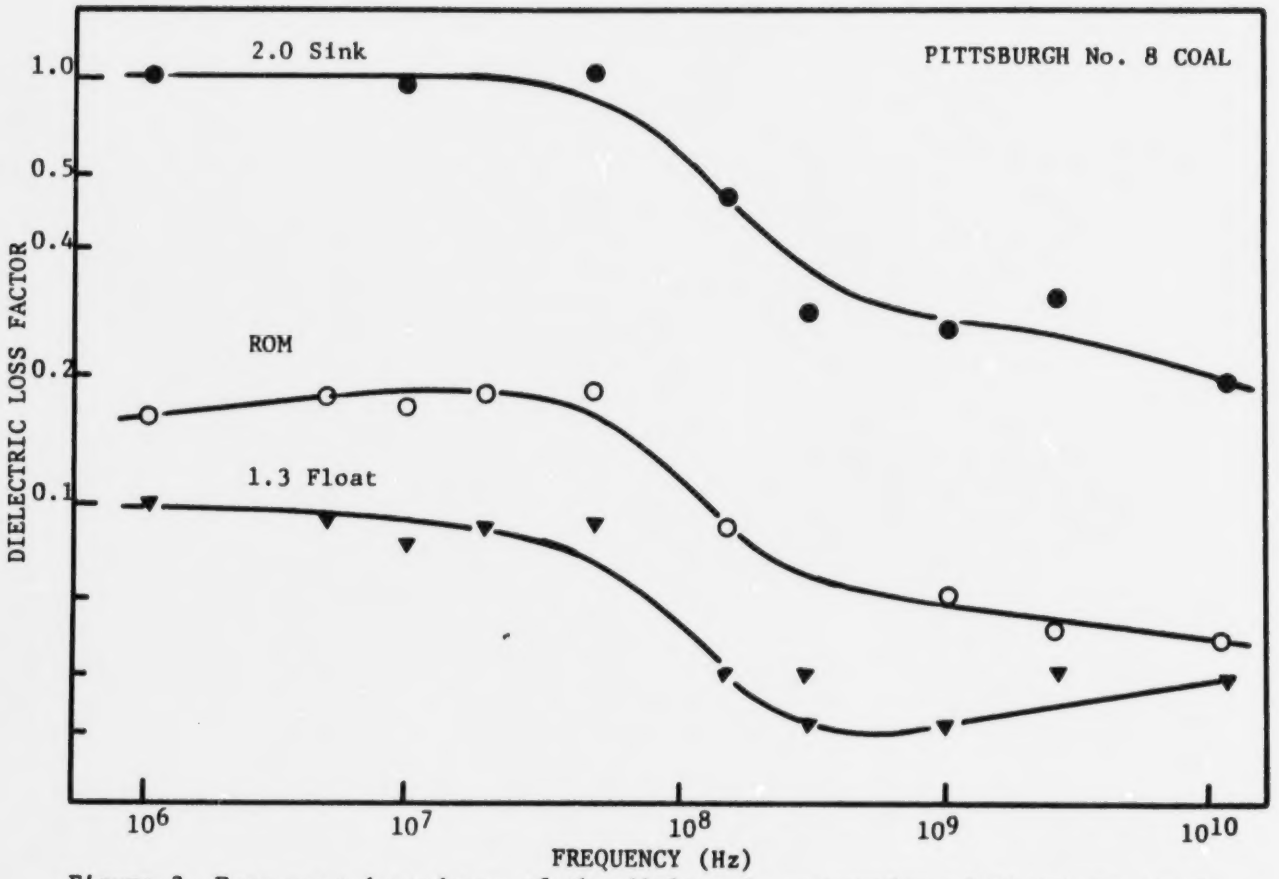

Figure 3. Frequency dependence of the dielectric properties of Pittsburgh No.8 pulverized coal at 22°C; run-of-mine (ROM), light (1.3 Float) and dense (2.0 Sink) fractions.

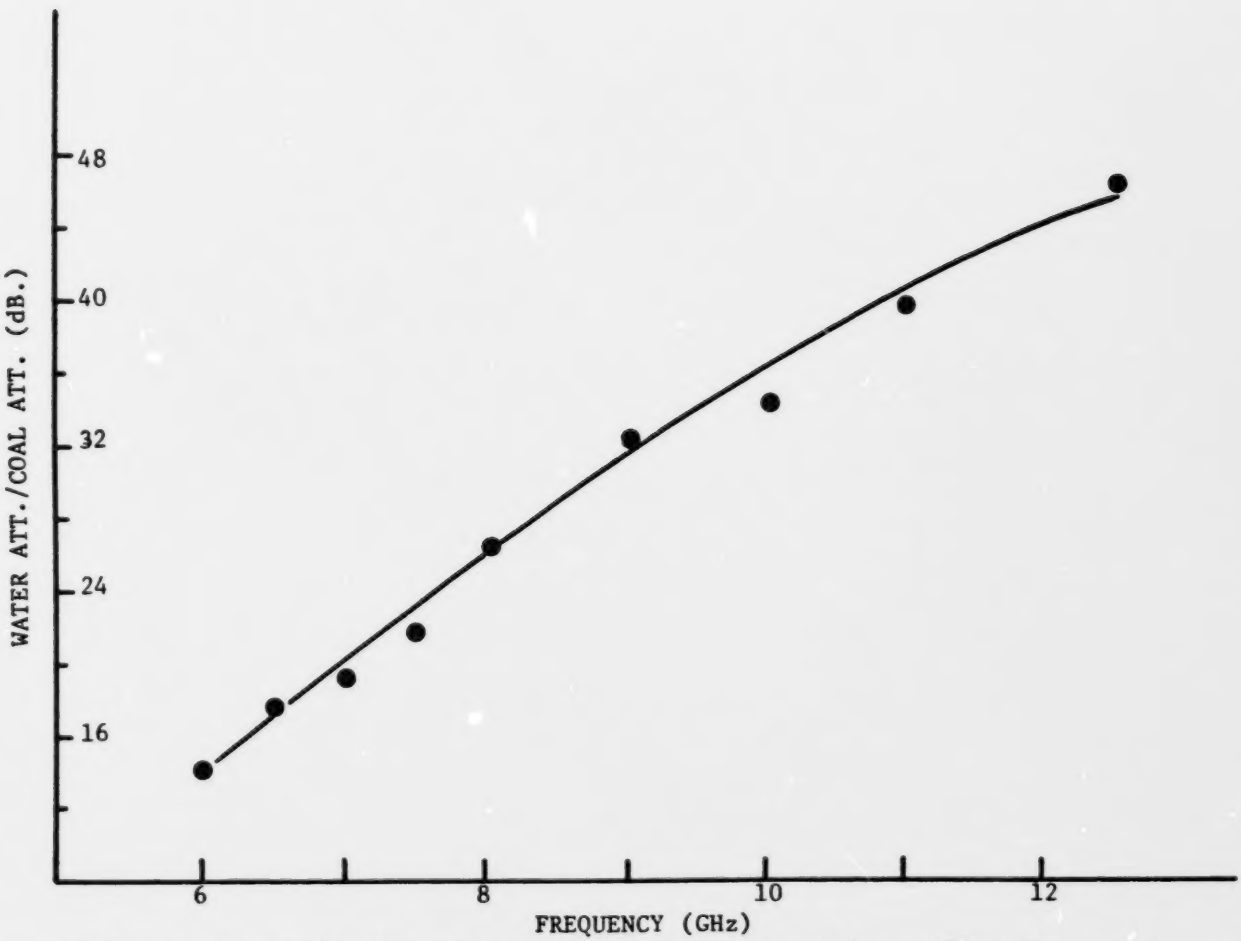

Figure 4. Ratio of water attenuation to coal attenuation as function of frequency.